QUALITY OF MODIFIED ATMOSPHERE PACKAGED "BARTLETT" PEARS AS INFLUENCED BY TIME AND TYPE OF STORAGE

S.R. DRAKE[1], D.C. ELFVING[2], S.L. DRAKE[3] and D.B. VISSER[4]

USDA, ARS-TFRL[1]
104 N. Western Ave.
Wenatchee, WA 98801

Accepted for Publication November 3, 2004

ABSTRACT

Commercially mature "Bartlett" pears for this study were obtained from local commercial packing facilities. In the first year, pears were packed in modified atmosphere bags and placed in boxes or packed normally (control) with an individual paper wrap around each pear plus a polyethylene liner in the box. Boxed pears from both types of packaging were stored in regular atmosphere (RA) storage at 1C for 30 or 90 days. In the second year, pears were packed normally and stored in both RA or controlled atmosphere (CA) storage for 45 or 90 days, or packed in modified atmosphere bags and stored in RA at 1C. After 45 days, normally packed pears from both RA and CA were removed from their initial storage, placed in modified atmosphere bags and returned to RA storage for an additional 45 days. Pears stored in modified atmosphere bags were superior in quality to normally packed pears stored only in RA storage and equal in quality to pears stored in CA for periods of 90 days. The quality of pears held in modified atmosphere bags under CA conditions deteriorated after only short periods of time (<45 days). Pears in modified atmosphere bags should be stored only in RA. Little or no quality advantage was evident if use of modified atmosphere bags was delayed regardless of prior storage type.

[1] Corresponding author. TEL: 509-664-2280; FAX: 509-664-2287; EMAIL: drake@tfrl.ars.usda.gov
[2] Horticulturist and Professor, Washington State University.
[3] Graduate Assistant, North Carolina State University, Department Food Science, Raleigh, NC.
[4] Research Assistant, Washington State University.

Journal of Food Processing and Preservation **28** (2004) 348–358.

INTRODUCTION

Modified atmosphere packaging (MAP) is yielding multiple benefits such as extended shelf life, enhanced appearance and retention of color and flavor, particularly for perishable fruits and vegetables that exhibit limited shelf life (Zagory and Kader 1988; Beaudry *et al.* 1992; Joles *et al.* 1994; Artes *et al.* 2000; Gil *et al.* 2001; Ding *et al.* 2002) or are minimally processed (Thompson 1988; Kader *et al.* 1989; Morales-Castro *et al.* 1994; Barry-Ryan *et al.* 2000; Gil *et al.* 2001; Hong and Gross 2001). The influence of MAP on quality of fruit with a naturally longer shelf life is variable. Some investigators report benefits on quality (firmness retention, reduced physiological disorders) in fruits with extended shelf life (Hewett and Thompson 1988; Geeson *et al.* 1991a; Zoffoli *et al.* 2002). Other researchers (Smith *et al.* 1989; Geeson *et al.* 1991b) indicate that problems can occur with the use of MAP and fruit, particularly injury in "Comice" and "Conference" pears. Hansen (2001) reported that MAP of "Bartlett" pears helped maintain quality, but that the risk of internal injury can be magnified with this type of package. Most of these studies stored product only in regular atmospheres (RA). Little information is available concerning product response in MAP stored in controlled atmospheres (CA).

"Bartlett" pears are normally stored for 45 days in regular atmosphere (RA) storage or 90 days in controlled atmosphere (CA) storage (Drake and Eisele 1997). The study reported here was conducted to compare the quality of "Bartlett" pears held under MAP conditions when exposed to RA and CA storage, and to evaluate the response of pears held in MAP after previous storage in RA and CA storage.

MATERIALS AND METHODS

"Bartlett" pears for this 2-year study were obtained from commercial packing facilities (Blue Bird, Inc., Peshastin, WA and Blue Star Inc., Cashmere, WA). All the pears were packaged at commercial maturity. In the first year (Blue Star, Inc.), pears from six grower lots were packed in MAP (Lifespan L257, Amcor Flexibles, Victoria, Australia) inside regular pear boxes or packed normally (control) with an individual paper wrap around each fruit plus a polyethylene liner placed around the inside of the box. Boxed pears from both types of packaging (MAP and normal) were stored in RA or CA (1.5% O_2 and 1.0% CO_2) storage at 1C. Pear quality was evaluated after 30 and 90 days of storage. In the second year (Blue Bird, Inc.), pears from four grower lots were stored in CA (1.5% O_2 and 1.0% CO_2) for 45 or 90 days, RA for 45 or 90 days, or in MAP for 45 or 90 days. After 45 days in RA or

CA storage, one-half of the pears from the two 45-day treatments were removed from storage, placed in MAP and returned to RA storage for an additional 45 days. Pear quality was assessed after 45 or 90 days of storage. Pears were also placed in MAP at harvest, held in CA (1.5% O_2 and 1.0% CO_2) and evaluated after 30 and 90 days.

Fruit quality was evaluated by using 20 pears immediately after removal from storage and 20 pears after an additional 2 days of ripening at 20C. Quality factors evaluated were firmness, external and internal color, soluble solids concentration (SSC), titratable acidity (TA), and visually rated disorders, peel defect, pedicel condition, scald, shrivel and internal breakdown. Firmness was determined by using the TA-XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) equipped with a 7.7-mm diameter probe. External and internal colors were determined with the ColorFlex (Hunter Assoc., Reston, VA) using the Hunter L*, a*, b* system and calculated hue values. SSC and TA were determined from a composite of juice expressed from longitudinal slices from each of 10 fruits. An Abbé-type refractometer with a sucrose scale calibrated at 20C was used to determine SSC. TA was measured with a Radiometer titrator, model TTT85 (Radiometer, Copenhagen, Denmark). Acids were titrated to pH 8.2 with 0.1 N NaOH and expressed as percent malic acid. Internal atmosphere of the MAP was determined by using a David Bishop Combo Gas Analyzer, model 280 (Heathfield, UK). After storage, pears were evaluated for peel defects, pedicel condition, internal breakdown and scald. Using a scale of 1 to 4 (1 = none/excellent; 2 = slight/good; 3 = moderate/fair; and 4 = extreme/poor), two laboratory personnel familiar with pears determined peel defects and pedicel condition. Internal breakdown (discoloration) and scald were evaluated by the same individuals, and observations were reported in percentage of total fruit affected. Data were analyzed as a completely randomized design with MSTAT-C 1988 using storage type as the main plot with storage time and ripening as subplots, and grower lots (4) as replications. Means showing a significant *F*-test were separated by using Tukey's HSD test.

RESULTS AND DISCUSSION

Both the peel and flesh color of pears were strongly influenced by MAP and time in storage, particularly when compared to pears in RA storage after 30 and 90 days (Table 1). After only 30 days in storage, peel color of MAP pears was much darker (lower L*), with more green and less yellow (higher hue) than pears in RA. In fact, even after 90 days of storage, pears in MAP retained more green color than did pears in RA after only 30 days. During ripening, peel color of MAP pears advanced very slowly, and even after 2 days

TABLE 1.
QUALITY ATTRIBUTES OF "BARTLETT" PEARS AS INFLUENCED BY MAP, TIME IN STORAGE AND RIPENING TIME

		Peel color		Flesh color		Firmness (N)	SSC (%)	TA (% malic)	SSC/TA ratio
		L*	hue	L*	hue				
Storage type	RA[†]	66.1	86.4	72.5a	84.2b	45.0	13.8	0.38	3.7
	MAP[‡]	59.8	97.8	73.6a	86.1a	56.4	14.0	0.44	3.2
Storage time	30	61.6	95.8	74.2a	85.6a	48.0	14.0	0.43	3.3
(days)	90	64.2	88.3	71.9b	84.6b	53.4	13.8	0.39	3.6
Ripe (days)	0	61.1	95.3	73.6a	85.7a	64.6	14.0a	0.43a	3.3b
	2	64.7	88.8	72.5b	84.6b	36.8	13.7b	0.35b	3.6a
Storage type x storage time									
RA	30	64.4b[§]	91.6c	73.9	84.8	45.9c	13.9ab	0.43a	3.3b
	90	67.7a	81.1d	71.1	83.5	44.1c	13.6b	0.34b	4.0a
MAP	30	58.8d	100.0a	74.4	86.4	60.9a	14.0a	0.44a	3.2b
	90	60.8c	95.6b	72.8	85.7	51.9b	14.0a	0.44a	3.2b
Storage type x ripe									
Control	0	64.4b	90.0c	73.3	84.7	60.6b	13.9	0.41	3.5
	2	67.7a	82.7d	71.7	83.7	29.4d	13.6	0.36	3.8
MAP	0	57.8d	100.7a	73.8	86.7	68.6a	14.2	0.46	3.1
	2	61.8c	94.9b	73.3	85.5	44.2c	13.9	0.43	3.3

[†] Normally packed fruit (paper wrap, polyliner, boxed), regular atmosphere (RA) at 1C.
[‡] MAP (modified atmosphere packaged; using LifeSpan bags, AMCOR Flexibles, Victoria, Australia) held in RA storage at 1 C.
[§] Means in a column within treatments not followed by a common letter are significantly different ($P \leq 0.05$) by Tukey's HSD test.
SSC = soluble solids concentration; TA = titratable acidity.

of ripening, the MAP pears were darker, with more green than RA pears immediately after removal from storage. Flesh color of MAP pears was greener than pears from RA storage, and this color difference remained constant during both storage and ripening time. Regardless of the type of storage, peel color was lighter and more yellow as time in storage and ripening progressed. Other researchers (Smith *et al.* 1989; Geeson *et al.* 1991a,b) indicated similar color changes with pears from MAP.

Pears held in MAP (Table 1) were firmer than pears in RA after either 30 or 90 days of storage, even though MAP pears declined in firmness 60.9–51.9 N between 30 and 90 days, whereas pears in RA lost no firmness, determined as 45.9 and 44.1 N, respectively. This difference in firmness between pears in MAP and pears in RA was evident by 30 days in storage, and was maintained for the remaining storage of 90 days. In addition, pears in MAP after 90 days of storage were firmer than pears in RA after only 30 days. CA

TABLE 2.
SUBJECTIVE QUALITY ATTRIBUTES OF "BARTLETT" PEARS AS INFLUENCED BY STORAGE TYPE, STORAGE TIMES AND RIPENING TIMES

		Peel defects (1–4)[†]	Pedicel condition (1–4)	Internal breakdown (%)	Scald incidence (%)
Storage type x	Storage time				
RA[‡]	30	1.0c[¶]	1.0b	0.0b	0.0b
	90	2.7a	1.4a	10.0a	32.0a
MAP[§]	30	1.0c	1.0b	0.0b	0.0b
	90	1.6b	1.1b	2.0ab	0.0b
Storage type x	Ripening (days)				
RA	0	1.5b	1.2ab	1.0ab	18.0a
	2	2.2a	1.3a	9.0a	14.0a
MAP	0	1.5b	1.1ab	2.0ab	0.0b
	2	1.2b	1.0b	0.0b	0.0b

[†] Graded on a scale of 1–4 (1 = excellent; 2 = good; 3 = fair; 4 = fair).
[‡] Normally packed fruit (paper wrap, polyliner, boxed) held in regular atmosphere (RA) at 1C.
[§] MAP (modified atmosphere packaged; using LifeSpan bags, AMCOR Flexibles, Victoria, Australia) held in RA storage at 1C.
[¶] Means in a column within treatments not followed by a common letter are significantly different ($P \leq 0.05$) by Tukey's HSD test.

storage type caused only a minimal and nonsignificant increase (<0.4%) in the SSC of pears compared to RA. Pears in MAP exhibited no difference in TA after 30 days, but were higher in TA after 90 days of storage than pears from RA. Differences in SSC and TA resulted in a higher SSC/TA ratio for pears in RA storage for 90 days. Boylson *et al.* (1994) indicated that consumers prefer apples with high SSC/TA ratios, and it is postulated that this will also be the case with pears.

Subjective scores for peel defects or general appearance of pears in MAP were superior to pears from RA, particularly after 90 days of storage (Table 2). In fact, the score for peel defects for pears in RA after 90 days was very high (>2.5) and would be considered unacceptable to most consumers. Ripening time had little or no influence on peel defects scores for pears in MAP, but peel defect scores for pears in RA increased substantially after 2 days of ripening. Scores for pedicel condition exhibited no differences after 30 days of storage, but were less acceptable for pears in RA than for pears in MAP after 90 days of storage. There were minor differences in the scores for pedicel condition during ripening. Contrary to a previous report (Hansen 2001), there were no significant differences in the amount of internal breakdown for pears in MAP and pears in RA storage. After 90 days of storage, similar amounts of internal breakdown were present in pears from both MAP and RA storage.

TABLE 3.
QUALITY ATTRIBUTES OF "BARTLETT" PEARS AS INFLUENCED BY REGULAR, MODIFIED OR CA STORAGE TIMES AND RIPENING

		Peel color		Flesh color		Firmness (N)	SSC/TA ratio	Peel defects (1–4)[††]	Scald incidence (%)
		L*	hue	L*	hue				
Storage type	Storage time								
RA[†]	45	63.6a[¶]	91.7b	70.8b	86.3a	39.3a	3.8bc	1.0b	<1.0b
	90	67.7b	83.8c	72.0ab	84.6b	30.6b	4.5a	2.3a	14.0a
MAP[‡]	45	61.2c	95.7a	70.7b	87.4a	39.0a	3.8c	1.0b	<1.0b
	90	60.3c	96.8a	72.7a	86.0a	39.7a	3.7c	1.3b	2.0b
CA[§]	45	59.9c	98.1a	73.2a	87.4a	38.8a	4.0bc	1.3b	3.0b
	90	60.3c	96.0a	72.4a	86.7a	37.8a	4.3ab	1.3b	<1.0b
Ripe (days)									
0		58.9b	98.2a	71.3b	87.3a	63.0a	3.9b	1.1b	<1.0b
2		65.4a	89.2b	72.6a	85.4b	12.1b	4.1a	1.6a	6.0a

[†] Normally packed fruit (paper wrap, polyliner, boxed) held in regular atmosphere (RA) at 1C.
[‡] MAP (modified atmosphere packaged; using LifeSpan bags, AMCOR Flexibles, Victoria, Australia) held in RA storage at 1C.
[§] Normally packed fruit (paper wrap, polyliner, boxed) held in controlled atmosphere (CA) at 1.5% oxygen and 1.0% carbon dioxide at 1C.
[¶] Means in a column within treatments not followed by a common letter are significantly different ($P \leq 0.05$) by Tukey's HSD test.
[††] Graded on a scale of 1–4 (1 = excellent; 2 = good; 3 = fair; 4 = poor).

However, after 2 days of ripening, internal breakdown was not present in pears stored in MAP, whereas pears in RA storage displayed 9% internal breakdown after 2 days of ripening. No scald was evident for pears in MAP storage after either 30 or 90 days of storage, and after 2 days of ripening. In contrast, pears held in RA storage displayed a high incidence of scald after 90 days of storage, and the scald level remained the same after 2 days of ripening.

"Bartlett" pears from either MAP or CA storage compared favorably, and both were superior in quality, to pears from RA storage (Table 3). Peel color (L* and hue) was similar for pears from either MAP or CA storage after either 45 or 90 days of storage. Pears from RA storage were lighter in color (higher L* values), with more yellow (lower hue values) after 45 days of storage than pears from either MAP or CA after 90 days of storage. This peel color difference for pears in RA storage was greater after 90 days of storage. Storage type exhibited little effect on flesh color. Flesh color was similar for pears after both MAP and CA storage. Flesh color of pears from RA storage was more yellow than the flesh color of pears from MAP or CA after 90 days of

storage. Pears in RA storage lost firmness as time in storage progressed from 45 to 90 days. Pears in either MAP or CA lost no firmness as time in storage progressed. The SSC/TA ratios were similar among pears from the three types of storage after 45 days. After 90 days, pears from RA and CA storage displayed similar SSC/TA ratios, and both were higher than the SSC/TA ratios of pears from MAP. This difference may indicate more desirable flavor for pears from RA or CA than from MAP. Peel defects were similar for pears after 45 days of storage regardless of the type of storage in question. After 90 days of storage, the peel defect scores for pears from RA were not as acceptable as the peel defect scores for pears from either MAP or CA storage, which were equal. As in the previous evaluation (Table 2), pears from RA storage displayed significant scald (14%) after 90 days (Table 3). Some scald was present for pears from both MAP or CA, but the amount was similar between the two types of storage. Two days of ripening produced pears with more color development, reduced firmness, increased peel defect scores, a higher SSC/TA ratio and enhanced scald, regardless of storage type or storage time.

A 45-day delay in the use of MAP packaging for pears from either RA (enhanced scald and internal breakdown), or CA (enhanced scald) storage reduced pear quality during an additional 45 days of storage (Table 4). After 90 days of storage, pears in CA and MAP storage were comparable in firmness, the amount of scald and the presence of internal breakdown either before or after ripening. Pears stored for 45 days in RA prior to MAP lost firmness at a slower rate and displayed more scald and internal breakdown after ripening than did pears from either CA or MAP (RA only, 90 days) storage. Pears stored for 45 days in CA prior to MAP did not lose firmness (did not soften) during ripening and displayed excessive amounts of scald (47%) after 2 days of ripening when compared to pears from CA or MAP (RA only, 90 days) storage. After 90 days of storage, the oxygen concentration in the MAP bags for the pears from CA storage for 45 days followed by 45 days of MAP in RA was <0.5% compared to >3.5% oxygen for pears in MAP (RA only, 90 days). This lack of oxygen (<0.5%) could easily be the reason for the absence of a ripening response (loss of firmness) during 2 days at ambient temperature. Several studies (Allen and Claypool 1948; Chen *et al.* 1981; Drake and Gix 2002) suggested that a storage atmosphere of 1–2% oxygen will retain acceptable good quality for pears. Hansen (2001) suggested that internal breakdown could be a problem with pears in MAP.

After 90 days, peel and flesh color and peel defects were comparable for pears from either MAP or CA only storage (Table 5). Pears stored for 45 days in RA prior to MAP exhibited a lighter peel color, with more yellow color than pears from either CA or MAP only, but similar in flesh color and peel defect scores. Pears stored for 45 days in CA prior to MAP exhibited darker

TABLE 4.
FIRMNESS, SCALD AND INTERNAL BREAKDOWN OF MAP "BARTLETT" PEARS: INTERACTION OF REGULAR AND CA STORAGE, AND RIPENING AFTER 90 DAYS TOTAL STORAGE

Storage treatment	Ripe (days)	Firmness (N)	Scald incidence (%)[‡‡]	Internal breakdown (%)
CA only[†] (90 days)	0	65.6a[††]	1.0c	<1.0b
	2	40.0c	3.3c	<1.0b
MAP, RA only[‡] (90 days)	0	67.6a	<1.0c	<1.0b
	2	40.0c	6.4c	<1.0b
45 days RA then MAP[§]	0	64.8a	<1.0c	<1.0b
	2	47.0b	23.0b	16.6a
45 days CA then MAP[¶]	0	64.5a	<1.0c	<1.0b
	2	62.3a	46.7a	<1.0b

[†] Normally packed fruit (paper wrap, polyliner, boxed) held in controlled atmosphere (CA) at 1.5% oxygen and 1.0% carbon dioxide at 1C.
[‡] MAP (modified atmosphere packaged; using LifeSpan bags, AMCOR Flexibles, Victoria, Australia) held in regular atmosphere (RA) storage at 1C for 90 days.
[§] Held loose in RA storage for 45 days, then MAP for 45 days in RA storage.
[¶] Held loose in CA storage (1.5% O2 and 1.0% CO2) for 45 days then MAP for 45 days RA storage.
[††] Means in a column within treatments not followed by a common letter are significantly different ($P \leq 0.05$) by Tukey's HSD test.
[‡‡] Total fruit.

peel color, with more green peel and flesh color, and significantly higher scores for peel defects than pears from either CA- or MAP-only storage. The SSC/TA ratio was most desirable for pears from CA-only storage, but comparable to the ratios for pears from RA storage for 45 days followed by MAP storage. The differences in the SSC/TA ratios regardless of storage treatment were minor, and are not of concern.

Pears were also packed in MAP and placed directly in CA storage. Pears under these conditions were unacceptable after only 30 days of storage, with large amounts of peel disorder and internal breakdown. Oxygen concentration in the MAP in CA storage was <0.5%, and the carbon dioxide concentration was 5.5%. The concentration of oxygen present in the MAP-only pears after 90 days ranged from 1.6 to 9.0%, and the carbon dioxide concentration ranged from 2.9 to 6.5%, with an average oxygen concentration of 4.7% and carbon dioxide concentration of 5.1%. These concentrations of oxygen and carbon dioxide compare favorably with the oxygen and carbon dioxide concentrations reported by Hansen (2001), who determined that good quality fruit was possible with the use of MAP if the oxygen and carbon dioxide concentrations were properly maintained. However, even at the smallest observed concentra-

TABLE 5.
QUALITY ATTRIBUTES OF MAP "BARTLETT" PEARS AS INFLUENCED BY TIME IN STORAGE AND REGULAR OR CA AFTER 90 DAYS TOTAL STORAGE

	Peel color		Flesh color		SSC/TA ratio	Peel defects (1–4)[‡‡]
	L*	hue	L*	hue		
Storage treatment						
CA only[†]	60.3b[††]	96.0b	72.4a	86.7b	4.3a	1.3b
MAP, RA storage only[‡]	60.3b	96.8b	72.7a	86.0b	3.7b	1.3b
45 days RA then MAP[§]	64.1a	89.8c	72.4a	85.5b	4.0ab	1.4b
45 days CA then MAP[¶]	55.7c	103.3a	73.2a	88.9a	3.8b	1.8a
Ripe (days)						
0	58.8b	98.3a	72.7a	87.3a	4.0a	1.0b
2	61.4a	94.7b	72.5a	86.3b	4.0a	1.8a

[†] Normally packed fruit (paper wrap, polyliner, boxed) held in controlled atmosphere (CA) at 1.5% oxygen and 1.0% carbon dioxide at 1C for 45 days, then modified atmosphere packaging (MAP) and stored in regular atmosphere (RA) for 45 days.
[‡] MAP (modified atmosphere packaged; using LifeSpan bags, AMCOR Flexibles, Victoria, Australia) held in RA storage at 1C for 90 days.
[§] Held loose in RA storage for 45 days, then MAP for 45 days in RA storage.
[¶] Held loose in CA storage (1.5% O2 and 10% CO2) for 45 days then MAP for 45 days RA storage.
[††] Means in a column within treatments not followed by a common letter are significantly different ($P \leq 0.05$) by Tukey's HSD test.
[‡‡] Graded on a scale of 1–4 (1 = excellent; 2 = good; 3 = fair; 4 = poor).

tion of oxygen (1.6%), there was no evidence of internal breakdown for "Bartlett" pears in this study. Pears that did display quality problems (45 days of CA then MAP for 45 days, or 90 days of MAP in a CA environment) exhibited oxygen concentrations of <0.5%.

CONCLUSIONS

"Bartlett" pears stored in MAP are superior in quality to pears stored in RA storage only, and equal in quality to pears stored in CA only. Operation of CA storage facilities is costly, and MAP may offer a cost-effective alternative that results in equivalent fruit quality to standard CA storage. Pears in MAP should only be stored under RA conditions. Pears in MAP held in CA storage conditions display reduced quality after only short periods of storage. Little or no quality advantage was evident if pears were stored initially in RA or CA conditions, and later placed in MAP when compared to pears placed in MAP shortly after harvest.

ACKNOWLEDGMENTS

The authors wish to express appreciation to the Washington Tree Fruit Research Commission for grant funds partially supporting this study.

REFERENCES

ALLEN, F.W. and CLAYPOOL, L.L. 1948. Modified atmosphere in relation to the storage like of Bartlett pears. Proc. Am. Soc. Hortic. Sci. *59*, 192–204.

ARTES, F., VILLAESCUSE, R. and TUDELA, J.A. 2000. Modified atmosphere packaging of pomegranate. J. Food Sci. *65*, 1112–1116.

BARRY-RYAN, C., PACUSSI, J.M. and O'BEIRNE, D. 2000. Quality of shredded carrots as affected by packaging film and storage temperature. J. Food Sci. *65*, 726–730.

BEAUDRY, R.M., CAMERON, A.C., SHIRAZI, A. and DOSTAL-LANGE, D.L. 1992. Modified-atmosphere packaging of blueberry fruit: effect of temperature on package O_2 and CO_2. J. Am. Soc. Hortic. Sci. *117*, 436–441.

BOYLSON, T.D., KUPFERMAN, E.M., FOSS, J.D. and BUERING, L. 1994. Sensory quality of "Gala" apples as influenced by controlled and regular atmosphere storage. J. Food Quality *17*, 477–495.

CHEN, P.M., SPOTTS, R.A. and MELLENTHIN, W.M. 1981. Stem-end decay and quality of low oxygen stored "d'Anjou" pears. J. Am. Soc. Hortic. Sci. *106*, 522–527.

DING, C.K., CHACHIN, K., UEDA, Y., IMAHORI, Y. and WANG, C.W. 2002. Modified atmosphere packaging maintains postharvest quality of loquat fruit. Postharvest Biol. Technol. *24*, 341–348.

DRAKE, S.R. and EISELE, T.A. 1997. Quality of Gala apples as influenced by harvest maturity, storage atmosphere and concomitant storage with Bartlett pears. J. Food Quality *20*, 41–51.

DRAKE, S.R. and GIX, R.D. 2002. Quality of "Anjou" pears from variable oxygen and high carbon dioxide controlled atmosphere storage. J. Food Quality *25*, 155–164.

GEESON, J.D., GENGE, P.M., SMITH, S.M. and SHARPLES, R.O. 1991a. The response of unripe Conference pears to modified atmosphere retail packaging. Int. J. Food Sci. Technol. *26*, 215–223.

GEESON, J.D., GENGE, P.M., SMITH, S.M. and SHARPLES, R.O. 1991b. Limitations to modified atmosphere packaging for extending the shelf-life of partly ripened Doyenne du Comice pears. Int. J. Food Sci. Technol. *26*, 22–231.

GIL, M.I., CONESA, M.A. and ARTES, F. 2001. Modified atmosphere packaging of fresh-cut tomato. Acta Hort. *553*, 703–704.

HANSEN, M. 2001. Modified atmosphere studied for pears. Good Fruit Grow. *52*, 36.

HEWETT, E.W. and THOMPSON, C.J. 1988. Modified atmosphere storage for reduction of bitter pit in some New Zealand apple cultivars. N. Z. J. Exp. Agr. Anim. Husb. *16*, 271–277.

HONG, J. and GROSS, K.C. 2001. Maintaining quality of fresh-cut tomato slices through modified atmosphere packaging and low temperature storage. J. Food Sci. *66*, 960–965.

JOLES, D.W., CAMERON, A.C., SHIRAZI, A., PETRACEK, P.D. and BEAUDRY, R.M. 1994. Modified-atmosphere packaging of "Heritage" red raspberry fruit: Respiratory response to reduced oxygen, enhanced carbon dioxide and temperature. J. Am. Soc. Hortic. Sci. *119*, 540–545.

KADER, A.A., ZAGORY, D. and KERBEL, E.L. 1989. Modified atmosphere packaging of fruits and vegetable. Crit Rev. Food Sci. *28*, 1–30.

MORALES-CASTRO, J., RAO, M.A., HOTCHKISS, J.H. and DOWNING, D.L. 1994. Modified atmosphere packaging of sweet corn on cob. J. Food Processing Preservation *18*, 295–304.

SMITH, S.M., GEESON, J.D., GENGE, P.M. and SHARPLES, R.O. 1989. The effects of modified atmosphere packaging and stage of ripeness on the quality of English pears during simulated marketing. 5th Intl. Cont. Atmos. Res. Conf. *1*, 315–324.

THOMPSON, A.K. 1988. *Controlled Atmosphere Storage of Fruits and Vegetables*. Culinary and Hospitality Industry Pub. Services, Weimer, TX.

ZAGORY, D. and KADER, A.A. 1988. Modified atmosphere packaging of fresh produce. Food Technol. *42*, 70–77.

ZOFFOLI, J.P., BALBONTIN, S. and RODRIGUES, J. 2002. Effect of modified atmosphere packaging and maturity on susceptibility to mealiness and flesh browning of peach cultivars. Acta Hort. *592*, 573–579.